Paper

Applying the radiated emission to the specific emitter identification

Janusz Dudczyk, Marian Wnuk, and Jan Matuszewski

Abstract—During the last years we have observed fast development of the electronic devices and electronic warfare systems (EW). One of the most principal functions of the ESM/ELINT system is gathering basic information from the entire electromagnetic spectrum and its analysis. Simultaneously, utilization of some tools of artificial intelligence (AI) during the process of emitter identification is very important too. A significant role is played by measurement and signature intelligence (MASINT) based on non-intentional emission (calls-radiated emission). This emission is a source of knowledge about an analysed emitter due to its incidental "chemical", "spectral" traces and non-communication emitter's characteristics. The process of specific emitter identification (SEI) based on extraction of distinctive radiated emission features is presented by the authors. Specially important is utilization of a database (DB) in the process of identifying a detectable radar emission.

Keywords— radiated emission, distance and homology function, measurement and signature intelligence, specific emitter identification.

1. Introduction

A radiated emission is presented by accessible sources of information in the context of electromagnetic compatibility (EMC). The condition which prevails when telecommunications (communication-electronic) equipment is collectively performing its individually designed functions in a common electromagnetic environment without causing or suffering unacceptable degradation due to electromagnetic interference to or from other equipments/systems in the same environment is defined and required by electromagnetic compatibility [8, 11]. A radiated emission is defined as a non-intentional (undesired) energy in the form of electromagnetic waves, which is propagated through into environment. Such an emission is called "radiated emission/interference" if it is parasitic radiation. It is an effect of electronic device working.

The evaluation of parasitic radiation level, generated by radio-electronic devices is realized by:

– qualification of mechanisms of radiated emission penetration into surrounding environment;

– measurement of radiated emission;

– measurement of conducted emission;

– creation of EMC strategy and international cooperation.

The present electronic intelligence system acquires basic information from different spheres of activities, e.g., signal intelligence (SIGINT), imagery intelligence (IMINT), human intelligence (HUMINT) and MASINT [1, 5, 6, 12]. Conventional electronic warfare support measures (ESM) systems measure some basic parameters of incoming radar signals. These basic (typical) parameters are as follows: radio frequency (RF), time of arrival (ToA), pulse width (PW), angle of arrival (AoA), amplitude (A) or pulse repetition interval (PRI). The characteristic of present battle-field electromagnetic environment, the process of acquisition and transformation data shows, that measured basic parameters are not enough during the process of source identification. Utilization of some specific properties of electronic devices functioning, e.g., radiated emission, can cause heightening probability of a correct identification.

2. Some methods of radiated emission analysis

The analysis of radiated emission propagated by electronic devices is based on checking, in a given frequency band, its radiation characteristic and qualification of components, i.e., electric and magnetical, of electromagnetic field or alternatively on determination of its radiated power on direction of maximum radiation [11].

Such measurement of radiated emission has been standardized (normalised) for many years and may be realized using open area test site (OATS) [2, 7, 11]. An OATS consists of the following elements: a ground plane fitted with integral turntable, a power connection, a scanning antenna dielectric mast with polarity switching and remote control (Fig. 1).

An open area test site exploitation (utilization) is determined by high costs of building and maintenance of OATS

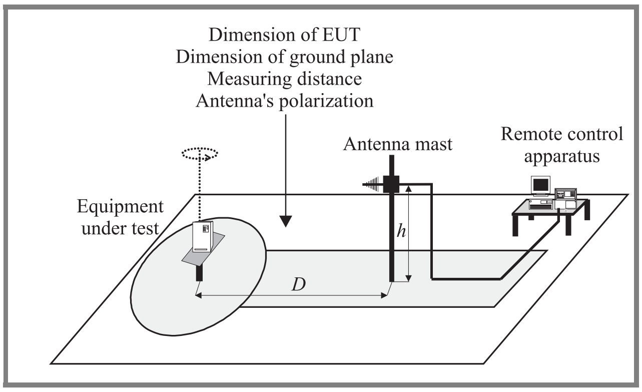

Fig. 1. Testing of radiated emission based on OATS.

and a permanent atmospheric influence. In this case, the measurement of radiated emission is realized using anechoic chambers, e.g., full and semi-anechoic chambers. Generally EMC chambers are used to test equipment for electromagnetic compatibility and susceptibility criteria. An anechoic chamber is a resonant cavity and by loading a chamber with specific loss absorber material and specially protective screen, a cavity and its associated resonances can be controlled. Thanks to using, for example, a hybrid ferrite-foam absorber, space of well-known and controlled conditions of electromagnetic waves propagation is obtained.

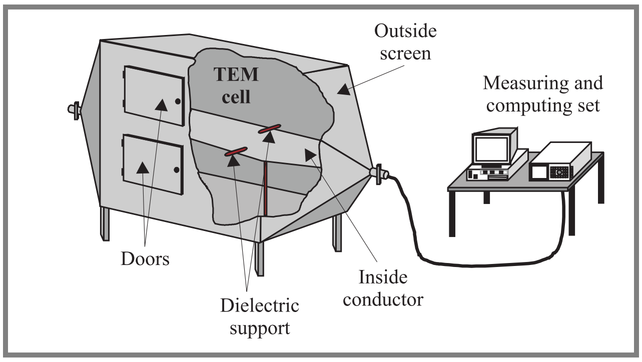

Fig. 2. Testing of radiated emission based on TEM cell.

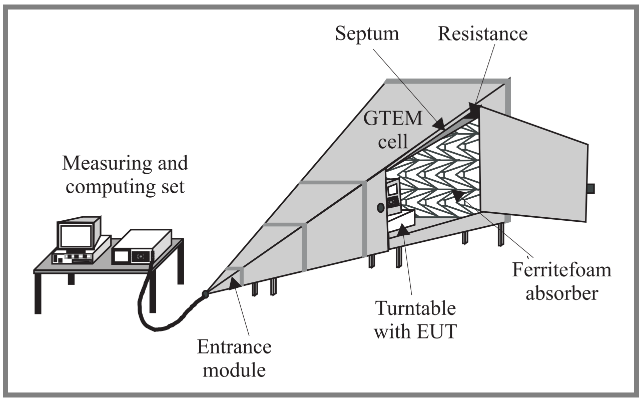

Fig. 3. Testing of radiated emission based on GTEM cell.

Sometimes some methods of radiated emission measurement are realized by using alternative manners, for example: a method based on transverse electromagnetic cell (TEM) or a method based on gigahertz transverse electromagnetic cell (GTEM). An alternative method calculates source parameters by determining its supplementary model of its emission (Figs. 2 and 3) [9, 10, 11].

3. The method of radar source identification based on using the radiated emission

The described method shown here is based on extracting some distinctive features from radiated emission, which identify an emission source. Applied prepared measuring method permits to get the set of frequency values, on which radar signals were registered. Gathered set of points is correlated with individual measured points and reflects the level of parasitic radiation. The set of measured points P is subordinated in the form of measured vectors, i.e., right-sided $\mathbf{p}^{\mathrm{p}}$ and left-sided $\mathbf{p}^{\mathrm{l}}$. These vectors are transformed into two-dimensional Euclidean space (Fig. 4).

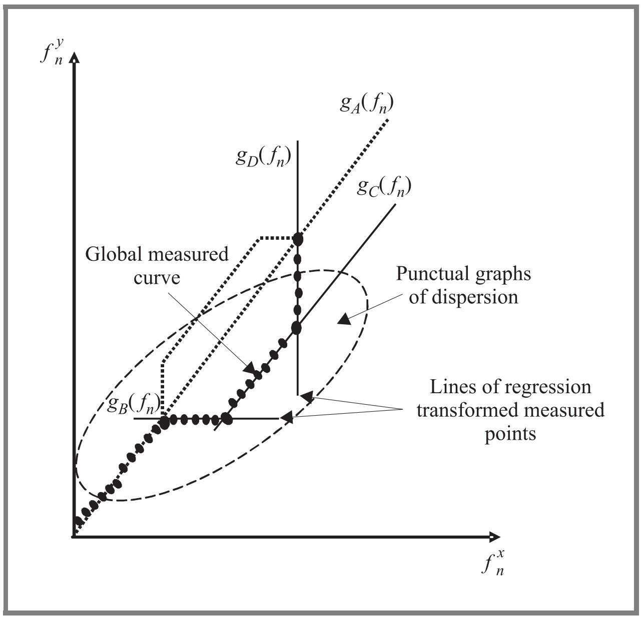

Fig. 4. The graphic image of measured points dispersion after transformation into two-dimensional Euclidean space.

Applying the regression analysis of second kind permits to specify some characteristic points. The global measured function $\hat{K}(f_n)$ is determined by calculated points P_n, where $n = 0, 1, \ldots, k_{gr}$. Figure 5 illustrates the shape of global measured function. The $\hat{K}(f_n)$ function is used to extract some radiated emission features, which modify

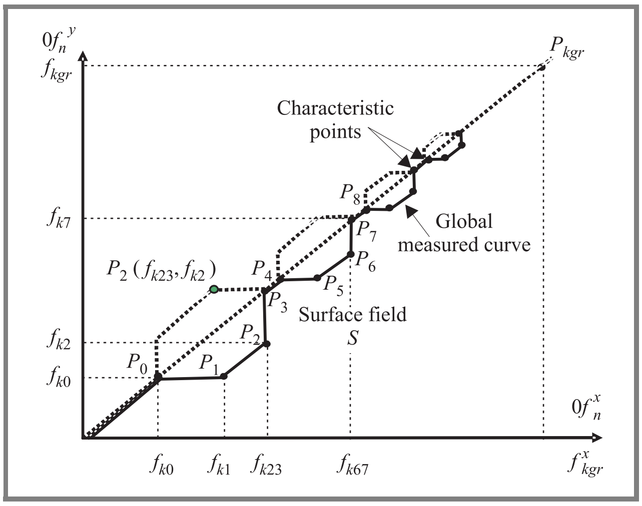

Fig. 5. The graphic image of generalized measured function crossing through appointed characteristic points.

structure of the extended vector parameters (EVP). At the end of the procedure, a radar emitter source identification is performed. During the final part of emitter identification process some distance functions (e.g., Euclidean, Mahalanobis, Hamming) are applied. The process of recognition is connected with the database, which is an important element in the modern electronic intelligence system. Some distinctive features extracted from radiated emission are used for special "radar signature" description in the database [4].

The global measured $\hat{K}(f_n)$ function in the form of a Lagrange polynomial k-degree, specified through $k+1$ characteristic points can be performed in the following way:

$$\hat{K}(f_n) = a_k f_n^k + a_{k-1} f_n^{k-1} + a_{k-2} f_n^{k-2} + \ldots + a_0 , \qquad (1)$$

where: $a_k, a_{k-1}, \ldots, a_0$ – some characteristic parameters of global measured function.

The $\hat{S}$ feature, defining the surface field value, extending from the figure of the generalized measured function $\hat{K}(f_n)$ in selected band $\langle f_n^{\min}, f_n^{\max} \rangle$ into the axis $0\, f_n^x$ will be expressed by appropriate equation:

$$\hat{S} = \int_{f_n^{\min}}^{f_n^{\max}} \hat{K}(f_n) d f_n$$

$$= \int_{f_n^{\min}}^{f_n^{\max}} \left(a_k f_n^k + a_{k-1} f_n^{k-1} + a_{k-2} f_n^{k-2} + \ldots + a_0 \right) d f_n . \qquad (2)$$

Simultaneously, the arc length of $\hat{K}(f_n)$ function as a distinctive $\hat{L}$ feature of radar emission will be expressed in accordance with appropriate equation:

$$\hat{L} = \int_{f_n^{\min}}^{f_n^{\max}} \left[1 + \left(\frac{\partial \hat{K}(f_n)}{\partial f_n} \right)^2 \right]^{\frac{1}{2}} d f_n$$

$$= \int_{f_n^{\min}}^{f_n^{\max}} \left[1 + \left(k a_k f_n^{k-1} + (k-1) a_{k-1} f^{k-2} + \ldots + a_1 \right)^2 \right]^{\frac{1}{2}} d f_n . \qquad (3)$$

An acquaintance of characteristic points $\left(P_0, P_1, P_2, \ldots, P_{kgr}\right) \in \hat{K}(f_n)$ makes its possible to calculate a Lagrange polynomial approximation of a k-degree. In this way the structure of basic radar vector parameters is modified by calculated features $\hat{S}$ and $\hat{L}$.

4. Conclusion

The analysis of a field size under the measuring function $\hat{K}(f_n)$ and calculation of a length of its arc into selected band $\langle f_n^{\min}, f_n^{\max} \rangle$ introduces to the radar signature additional features which modify the structure of basic parameters vector. These features in the form of $\hat{L}$ and $\hat{S}$ are executed by measurement and analysis of the radar radiated emission. A modern electronic intelligence system should utilize the above mentioned non-intentional property of electronic devices during the process of their identification. For these reasons some requirements connected with parasitic radiation of electronic devices belong at present to the basic category of requirements such as resistance to mechanical or climatic exposures. Taking all these points into consideration, applying the radiated emission to the specific emitter identification is an essential element in the formation of the examined system. The capability of an ESM/ELINT system to correctly identify detectable radar emissions in a dense environment is a key to their application in modern command, communication and control system. The problem of radiated emission is essential with respect to electromagnetic compatibility.

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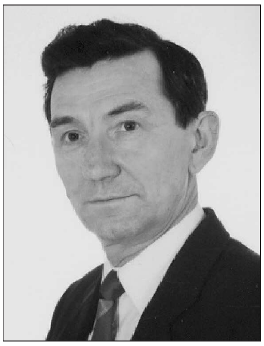

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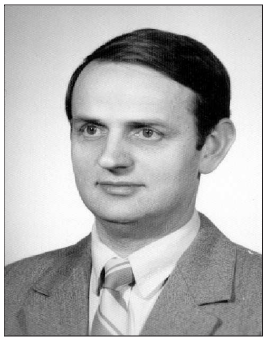

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